MUSEUM OF PRACTICAL GEOLOGY.

Government School of Mines and of Science applied to the Arts.

ON THE

IMPORTANCE OF CULTIVATING HABITS OF OBSERVATION.

(BEING THE INTRODUCTORY LECTURE TO THE COURSE ON MECHANICAL SCIENCE, SESSION 1851—1852.)

By ROBERT HUNT,
KEEPER OF MINING RECORDS.

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FOR HER MAJESTY'S STATIONERY OFFICE.

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In studying the phenomena of human progress we discover much that is of the highest interest to the philosopher, as illustrating the manner in which the powers of mind have been turned to the investigation of the works of creation, and displaying, at the same time, the beautiful reaction of each discovered truth in the improvement of man's social state.

The past must ever be the teacher of the present, and a bright or clouded future is entirely dependent upon our appreciation of its teachings.

Man, gifted with exalted powers, is the inhabitant of a most wonderfully constituted world, and according to the industry with which he exerts his reason he becomes the possessor of its wealth.

The animal necessities of the race are the primary exciters of the reasoning powers, and we find uncultivated man exerting his intelligence only to snare and destroy beasts, to furnish him flesh for food, or skins to shelter him from atmospheric changes. From this state he advances to a pastoral one, and studies to lessen his toils by domesticating animals, and thus escape from the perils and uncertainty of the chase. In the repose of a shepherd's life habits of contemplation appear to have had their earliest birth, and the phenomena of nature to have interested the human mind. Attention once awakened to the ever-changing, still recurring operations of organic life,—to the mysteries of alternating light and darkness,—the gradual and regular passage of the seasons,—the beauty of the stellar vault, and the meteoric displays which are for ever occurring in the the earth's atmosphere,—an imperfect science slowly crept into existence, the full development of which was long retarded

by the misty superstition with which man invested all things that he could not comprehend.

Without attempting to analyze the psychological progress of man in his study of the exacter sciences, which will, however, be found to be dependent upon his habit of methodizing ideas, we may, by confining our attention to the simple discovery of natural truths, see that all advancement has been the result of *experience*.

Facts frequently returning have at length solicited attention, and thus is cultivated habits of *observation*. By close attention new features are discovered in the phenomena; results which had long escaped casual and heedless glances are developed, and the mind is thus led up to the inquiry after the exciting cause. True science now begins, and the evidences of *experiment* are sought. A philosophical method is eventually developed, and its operations are displayed in the careful classification of observed phenomena, in the consideration of which the human mind necessarily demands the assistance of *theory;* and as this is constructed in accordance with true observations, or in obedience to the exuberent thoughts of an imaginative mind, is the discovery of truth accelerated or retarded.

To the record of careful observation we owe the first or initiative idea of every truth. The earliest duty, therefore, of every teacher is to train and educate the mind in habits of close and exact observation.

Man cannot create, but he is endowed with powers by which he may examine everything which is created, and by combination produce results which are to the uninitiated, but little short of a creation, when applied to the amelioration of some of the necessities of mankind. Human intelligence has bound the physical forces to do man service, and all the great applications of science may be referred to in proof of the position that human progress is directly dependent upon careful observation, and the habit of recording, in a systematic manner, the facts which have been thus developed to the mind.

The history of every science affords examples of this; the devious and uncertain wanderings of the astrologer, the alchemist, and the cosmogonist exhibit the severe struggles of truth

through the mazes of imagination; while the advancement of astronomy, of chemistry, and geology may be appealed to as expressive of the advantages of working diligently with a system of observation for our guide, and waiting patiently for the development of the truth.

It has been said, and said too by a great authority, that in experimental science we owe much to accident. Depend upon it, however, as a general rule, there are no accidents in science. It is true that often in the progress of an investigation an unexpected circumstance gives rise to a new train of inquiries; new ideas are the result, and discoveries the consequence. If that which may be regarded as an accident does not generate a clear idea, and generalize a correct system of inductive search, it remains a valueless fact.

Thales, of Miletus, observed, that amber being rubbed attracted light bodies. Here was a fact, probably of accidental discovery, which failed to produce a definite idea; and remember, nearly 2000 years passed away before man detected the truth that the *electron* of the Greek philosopher was a source of the all-diffusive agency, electricity. Galvani noted the convulsive movements of frogs, when the moist surface of their bodies was in contact with two metals of unequal affinity for oxygen; this generated a correct idea in the mind of Volta. Step by step induction has followed in this path, and we have, within a period of sixty years, the discovery applied to metallurgical processes of great utility, and to the valuable one of firing simultaneously any number of holes in the operation of blasting rocks, by which the sinking of shafts and the driving of levels in our mines are carried on with great rapidity and much economy. Following on the same tract Œrsted proved that a copper wire under the influence of an electric current became a temporary magnet. It was soon shown that an iron bar placed within an helix of such wire acquired most powerful magnetic properties; and within twenty years this knowledge has been applied to measure the tread of time, and to be the winged messenger of human thought, surpassing beyond all limits the speed of the "tricksy Ariel," and leaving the hurrying tempest like a laggard in its path. These facts were adduced by my colleague, Dr.

Playfair, in support of his arguments when discoursing of the value of abstract science; but as it will be my duty to show you in the progress of my course the experimental evidence to which I have now referred, I have not hesitated about repeating the striking illustration which these physical forces lend to the position I maintain. I cannot allow the present opportunity to pass without drawing attention to the evidence afforded by the attempts which have been made to apply the electrical element as an illuminating and mechanical power, of the danger of attempting to do so before we have acquired an accurate knowledge of all the phenomena which are involved in the conditions of the application. In the arc of light produced between the poles of a powerful voltaic battery we obtain the most vivid illumination which can be produced by artificial means. Ingenious mechanical contrivances have been devised to render the distance uniform between the charcoal points, which form the polar terminations of the wires, and thus to give steadiness to the electrical light, but since there is a constant transfer of the solid element from one pole to the other, the required steadiness has not yet been obtained. The question of the economy of this application, even if successful, may be conveniently embraced in connexion with the consideration of the application of electro-magnetism as a motive power. It has been stated, and is indeed now well known, that we can obtain an enormous attracting and repelling force by the agency of electro-magnets. In some cases magnets have been placed upon the periphery of a wheel, while others have been fixed upon a firm circle surrounding it. By mechanical contrivances the polar disposition of the magnets has been rapidly changed. The consequence of this is the exercise of an attracting and repelling power, by which the wheel is driven swiftly round. Another form of construction, offering some advantages, is a cylinder, around which clothed copper wire has been coiled, thus forming a hollow magnet, into which another solid magnet representing a piston is drawn, and from which, by changing the poles, it is afterwards repelled. By this means a long stroke is obtained, and by a crank any kind of machinery set in motion.

The first difficulty which has to be encountered here, is the very great rapidity with which the power diminishes through space. An electro-magnet which will sustain 220 pounds when the armature is in contact with its poles, exerts an attractive force of $40\frac{1}{2}$ pounds when the armature is at a distance of one fiftieth of an inch only. Now you will perceive that under any of the arrangements which have been adopted the moving and the fixed magnets could not be brought nearer together than the fiftieth of an inch; hence there is an immediate loss of one fifth part of the power we have produced.

The second difficulty to which I had the satisfaction of first directing attention in this country, although I have since been informed that it had been detected by Jacobi, is, that the moment the magnets begin to move there is a temporary loss of power, or, perhaps it would be more correct to say, there is a development of an opposing force, by which the mechanical power is again considerably diminished, and the greater the speed with which the magnets move, the more rapidly does this decline. The report made by order of the American government on Professor Page's electro-magnetic engine directs attention to this fact, which the reporting engineers were not able to explain. Mr. Hjorth, the most recent inventor and patentee of electro-magnetic engines, after the publication of my paper, observed the influence of these induced currents, and with a view to economy endeavoured to employ them in effecting the precipitation of the zinc, from the sulphate of zinc formed in the voltaic battery employed, but without success. Such are the difficulties which at present stand in the way of applying electricity as a motive power. It may be said, that these resolve themselves into questions of economy. Granted. The whole of this question I have investigated with the closest care, and the result is, that a grain of coal consumed in the boiler of a Cornish steam engine will lift 143 pounds one foot high, whereas one grain of zinc consumed in the voltaic battery will lift but 80 pounds through the same space. Now the cost of zinc is 216*d.* per cwt., while the cost of coal is but 9*d.* per cwt. It will be my duty to show and explain early in the present course of lectures that the

development of power, of whatever kind, is always accompanied by a change in the form of matter somewhere. To obtain a given amount of exertion from a horse we learn that it is necessary to give him a larger quantity of food than when he is at rest. If we desire to impel a locomotive engine at a high velocity we are compelled to supply an increased quantity of fuel, that steam may be generated with greater rapidity. We know of no development of force, whether heat, light, electricity, or muscular power, without such a change in the form of matter as amounts, to us, to its destruction. Muscle is consumed in every exertion of animal strength. Carbon and hydrogen in like manner are burnt in producing our artificial lights, either as gas, oil, wax, or tallow, and also in the production of heat, whether in our domestic fires, the furnaces of our manufactories, or the boilers of our steam engines. We evoke electricity by several methods of disturbance, but we have only now to consider that means of development which depends upon chemical action. Although we employ magnetic force, this is dependent on the power which is produced in the voltaic battery, and the zinc or any other element which may be employed is converted into some new form. Zinc, for example, is changed by the action of sulphuric acid in the battery into sulphate of zinc; and the advocates of the application of electricity as an illuminating or moving agent on the gronnd of economy state, and truly state, that the salt may be reduced and the metal revived. From my investigations of the whole question I feel assured that I state a truth in saying the coal employed in reproducing the metal would afford as much light, heat, or mechanical power as that obtained by the destruction of the metal in the first instance in the battery.

Let me not be misunderstood. In the present state of our knowledge I deem it hazardous to attempt to apply electro-magnetism instead of steam. Notwithstanding the rapid discoveries made in every branch of electrical research, and the great power which we can command in our voltaic arrangements, it must not be forgotten that the quantity of electricity obtained is exceedingly small in comparison with the quantity which exists in the elements constituting the voltaic battery. Dr. Faraday,

whose experimental researches in electricity must be regarded as the finest example of inductive investigation to be found in the annals of British science, and the most perfect exemplification of the philosophy of Bacon to which the student in physics can be referred, has proved that a single drop of water holds imprisoned in its liquid chains a quantity of electricity which equals that contained in an ordinary thunder-cloud. In every form of the voltaic battery a very large quantity of electricity is lost in passing from the liquid to the solid element, and the contrary; so that in overcoming the resistance nearly three fourths of the power is consumed.

Allow me to give another example of the value of close observation in connexion with magnetism. Dr. Faraday was the discoverer of the fact, that when a hollow helix of copper wire containing a core of soft iron was moved in front of or near the poles of a permanent steel magnet, electricity was evolved, and all the results of voltaism readily produced. Hence the formation of magneto-electrical machines; and in the great electro-plating establishments of Birmingham we may see the process carried on by the current thus generated by the revolution of coils of copper wire placed on an iron armature near the poles of an ordinary steel magnet.

To the true philosopher everything, howsoever insignificant to ordinary minds, is felt to deserve attention, and the minutest phenomena claim the most accurate study. A body falls to the ground,—a drop of water hanging from a rod, or resting on a leaf, assumes a spherical form. Nature is asked, Why is this? and the answer is the discovery of the law of gravitation, by which power each planet is retained in its orbitual path around the sun, and the entire solar system, held as completely in union as the particles of the water-drop, moved through space under the influence of a gravitating force resident in some far distant and probably unseen star. Reflection on the discovery of the planet Neptune must lead to the conviction of the truth of the Newtonian law of gravitation.

Up to the year 1804 the planet Uranus moved in its orbit without any appearance of disturbing influences; but at that period an accelerated motion became evident, and this con-

tinued until 1822, when the planet's rate of progress was retarded, and this has continued to the present time. It was felt that according to the law of planetary disturbance, the gravitating action of Jupiter and Saturn not being sufficient to explain the perturbations, it was probable that a mass of matter exterior to our known system was the exciting cause. In this state of the question the following problem became the subject of investigation to Mr. Adams, in England, and M. Leverrier, in France, unknown to one another:—"*Given the disturbances to find the orbit, and place in that orbit, of the disturbing planet.*" These geometers arrived at conclusions differing from each other only 3° 19′; and M. Leverrier having announced to Dr. Galle, of the Royal Observatory of Berlin, the position in which a new planet,—the disturbing cause,—should be found according to his calculation; on the very night of the day on which the letter was received the astronomer of Berlin discovered the planet Neptune in a point of space differing only 47′ from the mean of the two calculations. The planet Neptune, like the old planet Saturn, is surrounded by a ring. Allow me for one moment to direct attention to some experiments by Plateau on the condition of bodies relieved from the influence of gravitation, which appear to show that the remarkable phenomena of these two planets, with their luminous rings, are due to the influence of motion exerted under peculiar conditions. If oil is dropped upon water it swims; if upon alcohol it sinks; but if we make a careful combination of water and alcohol we obtain a fluid of the same specific gravity as the oil, and the globule of oil will swim in the very centre of the fluid, a perfect sphere. If into a properly arranged glass box we pass a fine wire through the sphere of oil, and by means of a handle cause it to revolve slowly, the sphere becomes an oblate spheroid; by increasing the motion we flatten it still more, until at a certain rate of revolution it becomes a disc, when a ring of oil is thrown off from the central globule, and although separated by intervening water, it revolves at precisely the same rate. It is not a little interesting thus to find mechanical science affording us the means of explaining the grander phenomena of creation.

The force of gravitation has its practical application in the ordinary forms of water-wheels, the falling water producing a continuous circular motion. In the hydraulic pressure engine, of which we have a beautiful model in the museum, the gravitating power of the water is the moving force. In the windmill we see the operation of the same power; and in the earlier engines, as those of Newcomen, Savery, and Watt's first single acting engine, the return of a heavy mass under the influence of gravitation and the atmospheric pressure—a result of the same principle—was the leading element of power. The works of Archimides and of Hero of Alexandria show us that the ancients were well acquainted with the operations of this agent, although they had not arrived at any correct idea of its law of action. It is to a neglect of the laws of gravitating force, and of the principle of action and reaction which prevails in every mode of motion, that the idle problem of producing perpetual motion has so frequently led ingenious minds aside from the path of usefulness which they would otherwise in all probability have pursued.

To continue our examination of the importance of minute observation, every step of progress from the employment of steam to produce a continuous motion, by Ptolomy Philadelphus, 130 years B.C., to the discovery by Watt of the expansive force of steam in 1782, might be quoted in exemplification.

We find Branca and Kircher employing the force of a jet of steam to drive the vanes of a wheel.

Baptista Porta observed the pressure exerted by confined steam, and he used it to raise water.

The discovery of the pressure of the air, and the investigations of Torricelli, Pascal, Guericke, and Boyle, led to the construction of engines by Worcester and Papin, in which the elastic force of steam and atmospheric pressure were combined in action.

Thomas Savery, carefully studying all that had been done previously, appears to have first conceived the correct *idea* of the force, and to have applied it with much greater success than any of his predecessors. In 1698 he got a patent for his discovery, calling it an invention "*for raising water, and occasioning motion to all sorts of millwork, by the impellent force of fire.*"

Newcomen, an ironmonger at Dartmouth, associated himself with Cawley, a plumber of the same place, and they together carefully investigated the phenomena of atmospheric pressure, and the formation of a vacuum by the agency of steam; and Newcomen certainly transformed an imperfect, and for many purposes a useless machine, into a really efficient steam engine, which could be applied profitably and safely to the most important uses. Newcomen should share a pedestal by the side of Watt; the ingenious contrivances of the obscure ironmonger of Dartmouth, the result of minute observation, have had much to do with the advance of civilization.

Of the inventions of Watt it is scarcely necessary to speak; the fertility of his genius is known to all; and the history of his progress informs us that every advance made by James Watt was a comment on the text I have chosen,—the value of observation. Of the importance of the inventions of James Watt well may Arago, in his Eloge, speak as follows:

"We have long been in the habit of talking of the age of Augustus and of the age of Louis XIV. Eminent individuals amongst us have likewise held that we might with propriety speak of the age of Voltaire, Rousseau, and Montesquieu. I do not hesitate to declare my conviction, that when the immense services already rendered by the steam-engine shall be added to all the marvels it holds out to promise, a grateful population will then familiarly talk of the ages of Papin and of Watt."

Heat, as a force or principle, most intimately connects itself with the steam engine, and we are hence led on to a consideration of some of the phenomena which are associated with calorific action. Water at the level of the sea boils at 212° of Fahrenheit when under ordinary conditions. The minute observations of a Belgian engineer have led to the discovery that when water freed from air is exposed to heat, ebullition does not commence until it arrives at a much higher temperature, and that then it occurs with almost explosive violence. He has also proved that if water in this state is brought to the temperature of 250° or 260°, and then a single drop of water containing air be allowed to fall into it, that the whole volume becomes agitated in a terrific manner, that indeed an explosion occurs.

Who amongst the thousands inhabiting those regions of the earth, where water is rendered solid by the reduction of the winter temperature, but has noticed the air bubbles enclosed in the transparent ice? None of these thousands discovered a great fact in this until Professor Henry was led to examine it. The result of that investigation has been the discovery of the remarkable truth, that water in the process of congellation actually squeezes out everything it may hold in solution, and becomes far more pure than it can be rendered by any other means. If water holding air, colouring matter, or saline bodies in solution is, while being frozen, kept in a state of slight agitation, the air, the colour, and the salt are all rejected alike, and a tasteless, colourless, transparent ice remains. It is curious to see how near a great truth men often are, and how long they allow it to escape them. It has been the constant practice of the Russian nobles to place their wines in ice until they were frozen, for the purpose of obtaining the small quantity of ardent spirit left in the centre of the mass. The water of the wine in freezing liberated the alcohol and flavouring matter, and a pungent cordial was thus obtained.

Ice thus free of air, if melted out of contact with the atmosphere, may be heated to nearly 300°, when, instead of boiling, it explodes. How nicely balanced are the conditions of all things in nature. We now learn that if water was not the all absorbing body which it is, it would be as dangerous to expose it to heat as gunpowder or any other explosive compound. This interesting discovery promises to throw some light upon many of the steam-boiler explosions, which will form a subject of inquiry in the present course. As another illustration of the manner in which we have, from the defective character of our education, allowed phenomena continually presenting themselves to us to escape attention, look to the investigations of Boutigny. That drops of water thrown upon hot iron arrange themselves into spheroids, and move about with a peculiar internal motion, is nothing new. Yet who amongst us suspected that these dancing drops were telling a story to man which will in all probability completely change our ideas of the properties of heat?

If two similar metal vessels are taken, and one is filled with water, which is allowed by the action of an ordinary fire to boil in the common way, we know what then takes place; but if we allow the other to become red-hot before we fill it with water, and when full maintain it at a red heat, the water will never boil. The former vessel will soon be emptied by the evaporation of the water in ebullition, but that water in the red-hot vessel forming itself into a spheroid, rolls about, it never gains a higher temperature than 150° or 160°, and it evaporates but slowly. Again, at the temperature of red-hot iron chemical affinity is suspended, and if we project into an iron crucible thus heated, any bodies having the most powerful affinity for each other, they will not enter into combination, but remain separate spheroids rolling around each other. The investigations of Boutigny in this path have proved that the repulsive power of heat at elevated temperatures is so great that the naked hand may be plunged into melted iron without injury, and that the wondrous feats of the magians and the tricks of the conjuror can be performed with impunity by the philosopher. No less than three patents have been taken out in England for generating steam with great rapidity. In one water was dropped into red-hot tubes, in another it was thrown upon red-hot plates of iron, and in another heated mercury was employed. It was thought that the water would be *flashed* into steam, and an immense power obtained, but in every instance failure followed the experiment. The investigations of Boutigny show the cause of failure, and prove the importance of experiment at every step we make in our endeavours to employ the great powers of Nature to do us service. Recently in France attempts have been made to employ water in this spheroidal state to work a marine engine. It being thought that as the vapour which escapes from the spheroidal water is of the high temperature of the surface upon which it is formed, that it would, from its extreme tension, furnish an enormous amount of power. The experiment has not been, even in this case, successful hitherto.

Mr. Woolfe, to whom the Cornish steam engine is indebted for many improvements, once tried an experiment in the

presence of Mr. Davies Gilbert and some other gentlemen of a very remarkable kind, the result of which bears curiously on the investigations to which I have just alluded. A measured quantity of water was placed in a boiler, all the safety valves were most carefully closed, and every chance of the escape of steam prevented. The fire was now got up, and for some time the steam gauge indicated a regularly increasing pressure. At length, to the surprise of all, the pressure was seen slowly, but gradually, to diminish, and although the boiler plates became so hot as to char the wood which surrounded them, this remarkable phenomenon continued, and when the boiler had cooled it was found that no water had escaped. These investigators conceived no correct idea from this hazardous experiment, but it was the Caignard de la Tour experiment of enclosing elastic fluids in hermetically sealed tubes, repeated on a large scale, and it showed, as all the experiments of Boutigny show, that notwithstanding our boasted knowledge we are yet ignorant of the laws which govern the operations of heat when its excitation is elevated. The decomposition of water by heat, as discovered by Mr. Grove, belongs to this class of phenomena, and Dr. Robinson, of Armagh, in considering the experiment, speculates on the probability, that at a certain point *heat* may be changed into a *chemical force*, similar to those radiations from the sun which effect the changes now familiar to all of you in the photographic processes, to which the term *Actinism* has been generally applied.

Although it will be my constant endeavour to explain with all care the useful applications of science; to show how thoroughly associated science and practice should be, I shall never fail to direct attention to those experimental evidences which enable us to interpretate the great phenomena of nature. As a cultivator of physical science I feel that I should sacrifice half of the advantages to be derived from the study, if I failed to show the satisfactory manner in which advancing science opens out to the contemplative observer new harmonies in creation, and tends to exalt the mind to higher and holier aspirations.

In connexion with heat, observation has proved to us numerous important points relative to its distribution over the earth's

surface. The Isothermal bands connect themselves with the phenomena of animal and vegetable distribution; and still more strikingly we are beginning to discover an intimate connexion between those regions of mean equal animal temperature and the great phenomena of terrestrial magnetism. The conditions of the ocean currents,—as, for instance, the Gulf stream setting northward from the Gulf of Mexico, and ameliorating the conditions of our own winters,—are worthy of careful study. The waters of the sea upon our western shores are always several degrees warmer than the adjoining land, and during last winter the ocean temperature was found to be two degrees higher than usual. May not the mildness of that season have been due to the influence of that current of water, warmed in inter-tropical climes, flowing northward, and yielding up its store of heat to the shores of these islands?

This ameliorating influence is strikingly shown in Norway. On the southern coasts of that country, which are sheltered from the Gulf stream by our own islands, the cereals will not grow; but further northwards, where the great current setting to the north of Scotland reaches the Norwegian shore, the climate is rendered sufficiently mild for the growth of grain crops.

Again, the trade winds and the monsoons are entirely dependent upon the operations of heat; and careful observation has shown that the tornadoes of the West Indies and the cyclones of the Indian Seas are entirely due to the action of currents generated by the intensely heated surface of the earth. Notwithstanding the valuable researches of Sir William Reid, and others, proving the rotatory character of these storms, I am not satisfied that we have yet had a correct theory of the physical causes in action to produce them.

These storms are revolving masses of air, with currents rushing from the circumference to the centre, and blowing up through that centre; these systems of air in violent motion being sometimes many hundreds of miles in diameter.

The simplest explanation appears to be, that a comparatively small column of air is formed by contact with the heated earth, which ascends with much rapidity. Take the example of a jet

of steam, which in rushing from a boiler under high pressure draws all surrounding light bodies into it, and urges them upwards; the same phenomenon is shown in rapidly flowing water. The jet generates rapid currents on every side; these increase the diameter of the moving mass, and it progresses, continually increasing in size; all the currents rushing in towards a moving centre, and upwards through that centre as through an inverted funnel. The barometer is the truthful indicator of a diminishing pressure as the centre of the storm approaches the place of observation; and thus the mariner is, by careful attention to this instrument, enabled to determine the exact position in which his ship may be placed relative to that centre.

The importance of a knowledge of the Law of Storms, and consequently of the means of escaping from the influence of these hurricanes, and of indeed employing them to aid the ship's progress, cannot be overrated. The development of the Law furnishes a fine instance of the value of observation.

Examples of a similar kind might be quoted in connexion with electrical science. Careful observation has dispelled the erroneous idea of metals being lightning attractors; and we must be charged with negligence if we allow any elevated building to be without its pointed rod, by which the thunder cloud may be quietly discharged. The lightning is no more attracted by a pointed metal rod than is the rain falling upon a housetop attracted by the pipes placed so as to allow the water to flow to a lower level; the rods furnish the channel through which the electricity freely flows; and tower or ship may be surely protected if provided with bands or rods of copper sufficiently large to carry off the accumulated electricity, and to restore the equilibrium of forces.

The electricity of mineral veins has been a subject of much interest; it having been supposed that the currents detected were indications of the operations of this agency in producing the metalliferous deposit. From my own investigations in the principal mines in Cornwall I am disposed to consider these electrical currents as due to the chemical decomposition going on within the lode itself. It must, however, be admitted that the peculiar disposition of dissimilar ores within the same

mineral lode, the alteration in the character of the lode or vein after a dislocation has taken place, the generally uniform direction of lodes, and many other phenomena which it will fall to the province of my colleague, Mr. Warington Smyth, to describe, appear to show the probability of such a power as electricity, in some of its modifications, being the exciting agent. This is one of those extensive subjects which yet remains open for the investigation of an intelligent and industrious observer.

In a course of lectures which is to embrace a consideration of the physical forces the phenomena of the solar radiations cannot be omitted. The practice of photography belongs to these, and furnishes another choice example of my text,—the value of observation. Omitting, however, all mention of the useful applications of photography as a means of making philosophical instruments self-registering, allow me to state that a careful investigation of the thermic influences of the solar spectrum, associated with a physical analysis of various transparent media, led me to the discovery of a glass, but slightly coloured green, which possesses the property of separating and keeping back a class of solar rays remarkable for their scorching power, and which, without obstructing any of the necessary radiations, thus protects the tropical plants in the great conservatory of the Royal Botanic Gardens of Kew from the injurious influences of scorching sunshine.

The solar spectrum exhibits several distinct phenomena. Light, heat, and chemical action are evident; and these give rise to electrical disturbance. Beyond these a class of radiations have been detected, which have the combined action of the heating and chemical rays, but which are in many respects dissimilar to either. These rays increase in quantity relatively to the other principle as the seasons advance; they being most abundant in the autumn; when, in all probability, they perform an important part in the ripening of fruit. These are the rays which, it has been found, operated to produce a kind of scorching on the leaves of those plants which grow in houses glazed with a white glass. To obviate this, was the problem submitted to my care; and the suns of two summers and autumns have shown that my experiments did not deceive me. No case of

scorching has taken place upon any of the plants in the beautiful palm-house in Kew Gardens. It is important to state than an entire absence of manganese in the manufacture of the glass is demanded, and that the addition of a small quantity of oxide of copper is required.

Did time permit me I might proceed to show you, that even those discoveries which have most the character of accidents, as that of iodine by a soap-boiler, and of the beautiful blue pigment, ultramarine, in the manufacture of soda; by generating ideas, which led to their scientific investigation, ceased to be so. Both iodine and artificial ultramarine form large branches of industry both having result from careful observation, and in the latter instance we have produced a pigment which formerly cost eight guineas an ounce now to be obtained for less than eight shillings a pound. Learn to observe closely and accurately, and numerous other similar results must be the reward.

Mechanical science embracing a consideration of all the means of employing the powers of Nature to aid man in subduing Nature, is necessarily a wide field. It will be my object in the first course of lectures on applied Physics to deal simply with the rudiments of our science, advancing gradually to the higher phenomena. To show the intimate connection of science and practice, the one aiding and advancing the other, will be my constant care, and in expounding the discoveries in Natural Science I hope to lead the mind to the study of those enobling truths which constitute a

> " Divine Philosophy!
> Not harsh and crabbed as dull fools suppose,
> But musical as is Apollo's lute,
> And a perpetual feast of nectar'd sweets,
> Where no crude surfeit reigns."

LONDON:
Printed by GEORGE E. EYRE and WILLIAM SPOTTISWOODE,
Printers to the Queen's most Excellent Majesty.
For Her Majesty's Stationery Office.